Field Preparation for High Level Control

F. Fehr

HES 98/6347/E

1. INPUT SIGNALS FOR HIGH LEVEL CONTROL

The Input Signals of the High Level Control system (HLC) are the measured variables of the controlled systems (kiln, cooler, mill). In the following a selection of the normally used input signals is indicated.

Selection of Input Signals

Wet kiln

- Sintering zone temperature (Pyrometer)
- Secondary air temperature (if available)
- Amps of kiln drive (Torque)
- O2/CO/NOx at kiln inlet
- Temperature at chain zone
- Backend temperature
- Backend pressure
- Kiln hood pressure
- Any other significant process variable used by the kiln operators

Preheater kiln

- Sintering zone temperature (Pyrometer)
- Secondary air temperature (if available)
- Amps of kiln drive (Torque)
- NOx at kiln inlet or at preheater exit
- O_2/CO at kiln inlet
- Kiln inlet temperature
- Kiln inlet pressure
- Kiln hood pressure
- Preheater exit temperature or second stage from top
- Preheater exit pressure
- O_2/CO at preheater exit
- Any other significant process variable used by the kiln operators

Precalciner kiln

- Basically the same signals as for preheater kilns, but additionally:
- NOx at kiln inlet
- Temperature exit lowest cyclone stage
- Tertiary air temperature

Lepol kiln

- Sintering zone temperature (Pyrometer)
- Secondary air temperature (if available)
- Amps of kiln drive (Torque)
- O_2/CO/NOx at kiln inlet
- Temperature in hot chamber of Lepol grate (Pyrometer or Thermometer)
- CO/O_2 after intermediate fan
- Temperature intermediate fan
- Pressure in hot chamber above grate
- Pressure in hot chamber underneath grate
- Kiln hood pressure
- Any other significant process variable used by the kiln operators

Clinker cooler

- Air rates of the individual fresh air fans
- Pressures of chambers 1, 2, 3
- Exhaust air temperature
- Temperature of cooler plates
- Middle air temperature (if any)

Cement mill

- KW of mill motor
- KW of bucket elevator
- Rate of separator returns (t/h)
- Noise level by electronic ear
- Temperature/pressure at mill inlet and outlet
- Production rate, e.g. belt weigher, pressure of pneumatic transport, etc.

1.1 Checklist: Assignment of Input Signals

INPUT SIGNALS	Min.	Max.	Target

Name of Signal, Value

Sensor:
Location:
Significance:
Stability:
Comment:

Name of Signal, Value

Sensor:
Location:
Significance:
Stability:
Comment:

Name of Signal, Value

Sensor:
Location:
Significance:
Stability:
Comment:

Name of Signal, Value

Sensor:
Location:
Significance:
Stability:
Comment:

Name of Signal, Value

Sensor:
Location:
Significance:
Stability:
Comment:

1.2 Example of a Checklist

INPUT SIGNALS		Min.	Max.	Target
1)	Secondary air tempe rature	650°C	1040°F	815°C
		1200°F	1900°F	1500°F
	Sensor:	o.k.		
	Location:	o.k.		
	Significance:	Indication is sensitive. Tendency is o.k.		
	Stability:	o.k.		
	Comment:	Measuring equipment is adequate. Useful signal for LINKman II. Upper/lower limits are exceeded, therefore the limits have to be adjusted.		
2)	Cooler exhaust air temperature	95°C	230°C	150-175°C
		200°F	450°F	300-350°F
	Sensor:	o.k.		
	Location:	o.k.		
	Significance:	not looked at		
	Stability	not stable due to unstable cooler operation.		
	Comment:	Measuring equipment is adequate.		
3)	Clinker temperature	-	-	
	Sensor:	o.k.		
	Location:	Existing location gives no representative signal.		
	Significance:	not looked at		
	Stability:	not looked at		
	Comment:	As a better location is not available, this temperature should not be considered for automatic control.		
4)	Grate speeds of cooler	-	-	
	Sensor:	-	-	
	Location:	-		
	Significance:	-		
	Stability:	-		
	Comment:	unproblematic signal.		

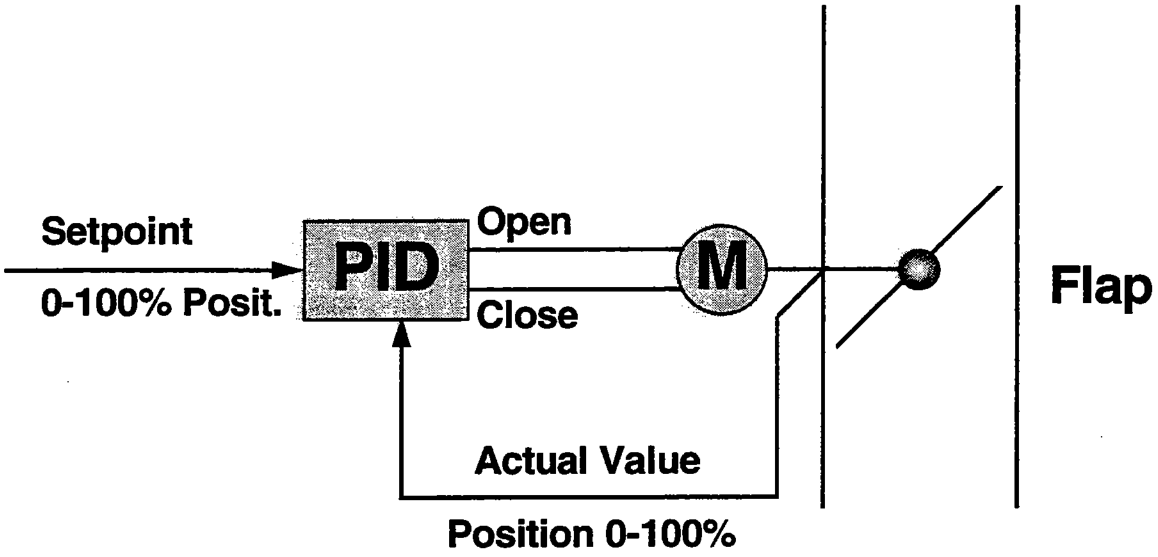
2. OUTPUT SIGNALS FOR HIGH LEVEL CONTROL

2.1 Primary Control Loops, Actuators

Basically all High Level Control output signals go as setpoints to primary control loops which then drive actuators.

Example:

Figure 1:



Example of a Primary Loop

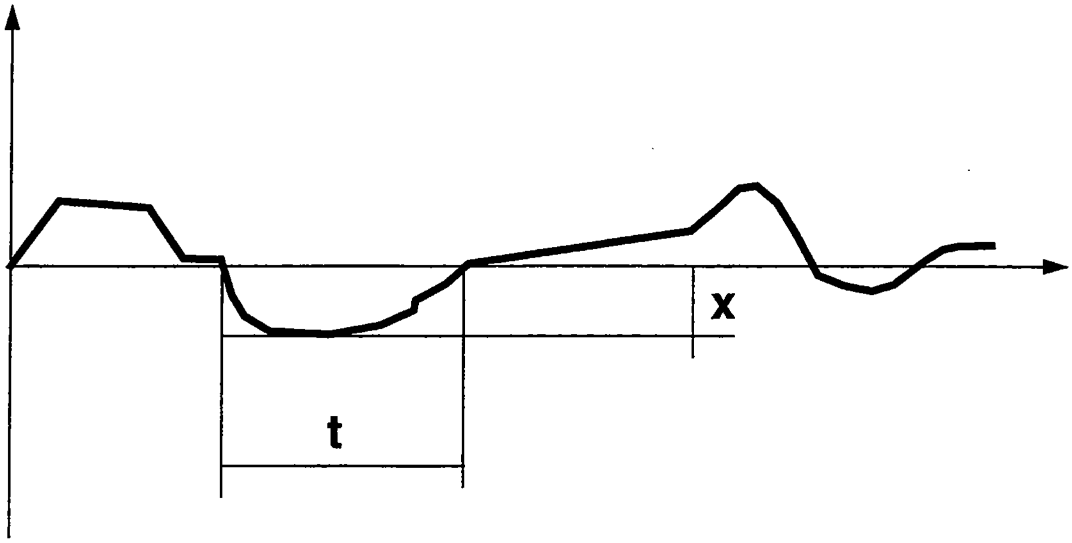
The behaviour of the variable controlled by the primary loop is influenced by the following factors:

- repeatability of the sensor (specifications)
- absolute accuracy of sensor (calibration)
- type of actuator: continuous, step-wise
- tuning of PID controller
- deadband to protect actuator
- disturbances from outside (e.g. flushing material)

For HLC the primary loops have to fulfil the following criterias:

1) Tolerable deviation from setpoint

Figure 2:



Tolerable Deviation from Setpoint

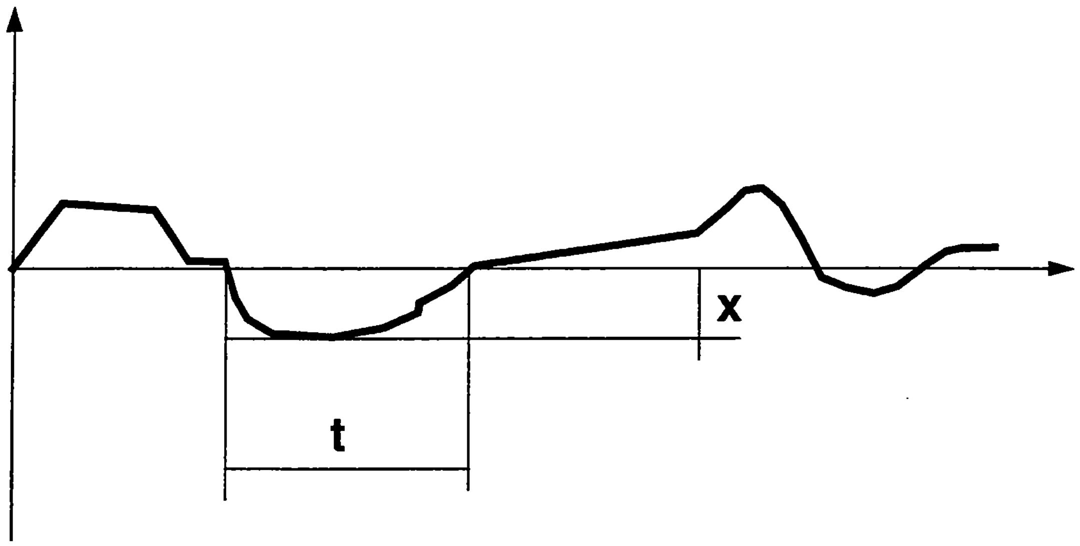
Δ x: max. tolerable deviation during a time > Δ t

Δ x and Δ t depend upon what is controlled by the primary loop (e.g. coal, slurry to a wet kiln)

2) Sensitivity of setpoint change

What is the minimum applicable setpoint change that causes a reaction of the controlled variable?

Figure 2:



Tolerable Deviation from Setpoint

The criterias which have to be fulfilled are given in the following list for every type of primary loop. Most of the loops are not critical so that no criterias for the tolerable deviation are given:

Table 1

	Tolerable Deviation from Setpoint		**Sensitivity of Setpoint Change**
	x[% of Span]	t [min]	SPmin [% of Span]
Cooler			
Volume rate fresh air fans			
- speed	-	-	0.5%
- damper position	-	-	1.0%
Kiln hood pressure			
- speed	-	-	0.5%
- damper position	-	-	1.0%
Grate speed ratio	-	-	1.0%
Under grate pressure	-	-	1.0%
Kiln			
Kiln fan			
- fan speed	-	-	0.5%
- damper position	-	-	1.0%
Kiln drive	-	-	0.5%
Fuel rates	3%	0.5	0.5%
Feed: wet	3%	10.0	0.5%
preheater	3%	2.0	0.5%
Dust insufflat. rate	10%	0.5	1.0%
Tertiary air dampers	-	-	1.0%
Intermed. fan (Lepol)	-	-	0.5%
Lepol grate speed	-	-	1.0%
Water to granulator	-	-	1.0%
Mill			
Mill feed	3%	0.5	1.0%
Separator speed	-	-	0.5%
Cooling air fan	-	-	
- fan speed	-	-	0.5%
- damper position	-	-	1.0%
Water injection	-	-	1.0%

2.2 Example of a check list 1

PID Loop: **Kiln drive**

	HAC Code	0%	to	100%	Unit
Setpoint:	.....	.....	to	.....	[ ]
Actual Value:	.....	.....	to	.....	[ ]
Manipulated Variable: (actuator)	.....	.....	to	.....	[ ]

Visual check of actuator:

Tuned:

Parameters: K_P = ... T_I = ... [ ] T_D = ... [ ]

Max. deviation: Delta x = ... [% of span]
during: Delta t = ... [min]

Sensitivity: .... [% of span]
SPmin =

Remarks:

PID Loop: **Precalciner fuel rate**

	HAC Code	0%	to	100%	Unit
Setpoint:	.....	.....	to	.....	[ ]
Actual Value:	.....	.....	to	.....	[ ]
Manipulated Variable: (actuator)	.....	.....	to	.....	[ ]

Visual check of actuator:

Tuned:

PID Parameters: Kp = ... T_I = ... [ ] T_D = ... [ ]

Max. deviation: Delta x = ... [% of span]
during: Delta t = ... [min]

Sensitivity: .... [% of span]
SPmin =

Remarks:

2.3 Example of a check list 2

PID Loop: **Main burner fuel rate**

	HAC Code	0%	to	100%	Unit
Setpoint:	.....	.....	to	.....	[ ]
Actual Value:	.....	.....	to	.....	[ ]
Manipulated Variable: (actuator)	.....	.....	to	.....	[ ]

Visual check of actuator:

Tuned:

Parameters: Kp = ... T_I = ... [ ] T_D = ... [ ]

Max. deviation: Delta x = ... [% of span]
during: Delta t = ... [min]

Sensitivity: .... [% of span]
SPmin =

Remarks:

PID Loop: **Kiln feed**

	HAC Code	0%	to	100%	Unit
Setpoint:	.....	.....	to	.....	[ ]
Actual Value:	.....	.....	to	.....	[ ]
Manipulated Variable: (actuator)	.....	.....	to	.....	[ ]

Visual check of actuator:

Tuned:

PID Parameters: Kp = ... T_I = ... [ ] T_D = ... [ ]

Max. deviation: Delta x = ... [% of span]
during: Delta t = ... [min]

Sensitivity: .... [% of span]
SPmin =

Remarks:

3. INTERFACE TO PROCESS CONTROL SYSTEM

For any process control application, the High Level Control System needs to read data from the process (inputs from sensors) and to write data to the process (outputs to primary control loops). Moreover, for kiln/mill control, the High Level Control System requires also operator inputs such as:

- operating targets (NOx, O_2, etc.)
- operator setpoints (kiln feed, fuel feed, etc.)
- laboratory data (clinker factor, fuel heat value, % free lime etc.)

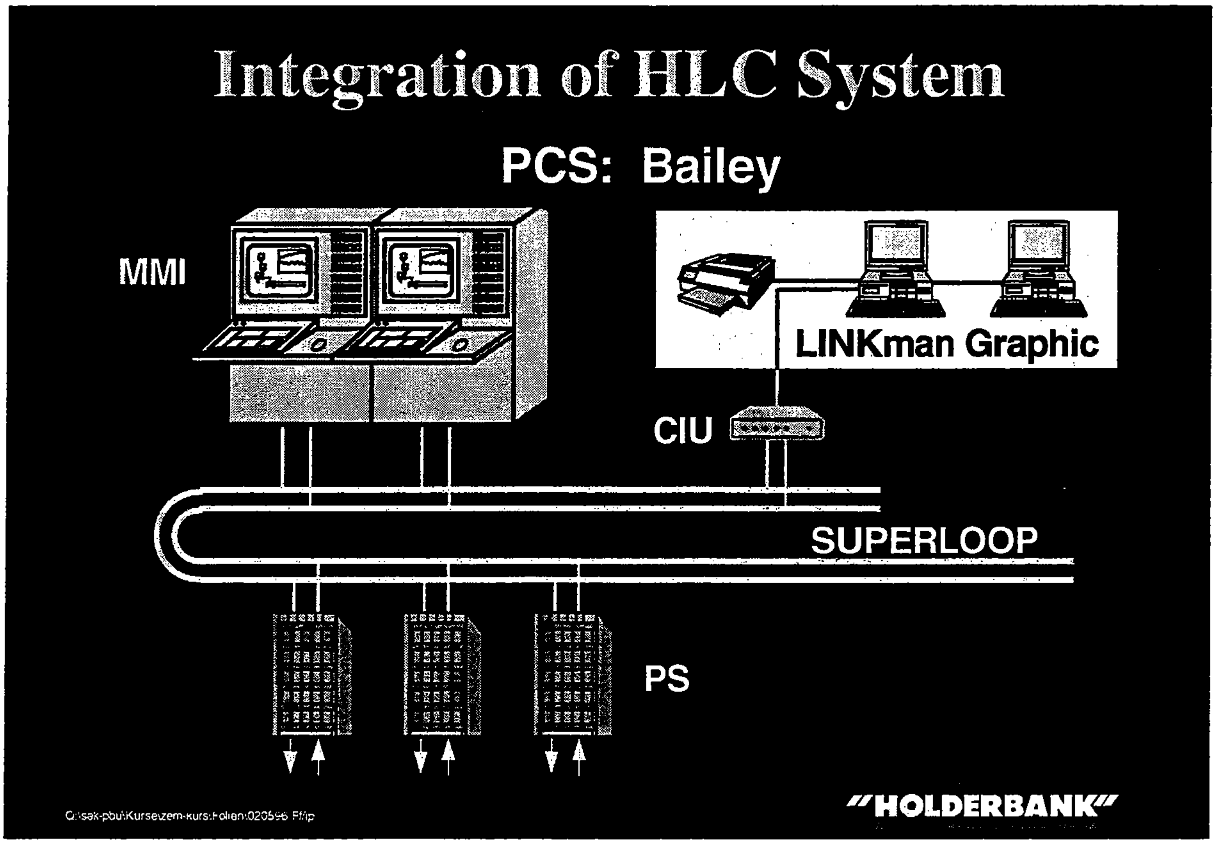
These inputs can be entered either from the LINKman II or from the Process Control System (PCS) The data communication between the PCS and the HLC is mostly based on a RS 232/422 serial link with the PCS brand specific communication protocol. The data set for exchange has to be pre-processed and stored in a specific memory location to be available for the data communication software.

For a kiln application for example, process data are accessed every 10 seconds and outputs are sent every 5 minutes, or with higher frequency if required, to update setpoints. The kiln strategy, for example runs every minute.

To connect the LINKman II to the PCS, two possible configurations are proposed:

- If the PCS has a bus connecting the whole plant (plant loop), then the LINKman II is interfaced by using a serial link to the interface box of the loop. An example is presented on the next page where the LINKman II is interfaced through a CIU (Computer Interface Unit) to a Bailey Network 90.
- If the PCS is structured according to the plant departments, the LINKman II has access to the individual departments through individual serial lines. The second picture shows a typical interface in a application where an Allen Bradley Programmable Logic Controller is used in connection with the HOLDERBANK ODH system as Men Machine Interface (MMI).

Figure 4:



Integration of HLC System

PCS: Bailey

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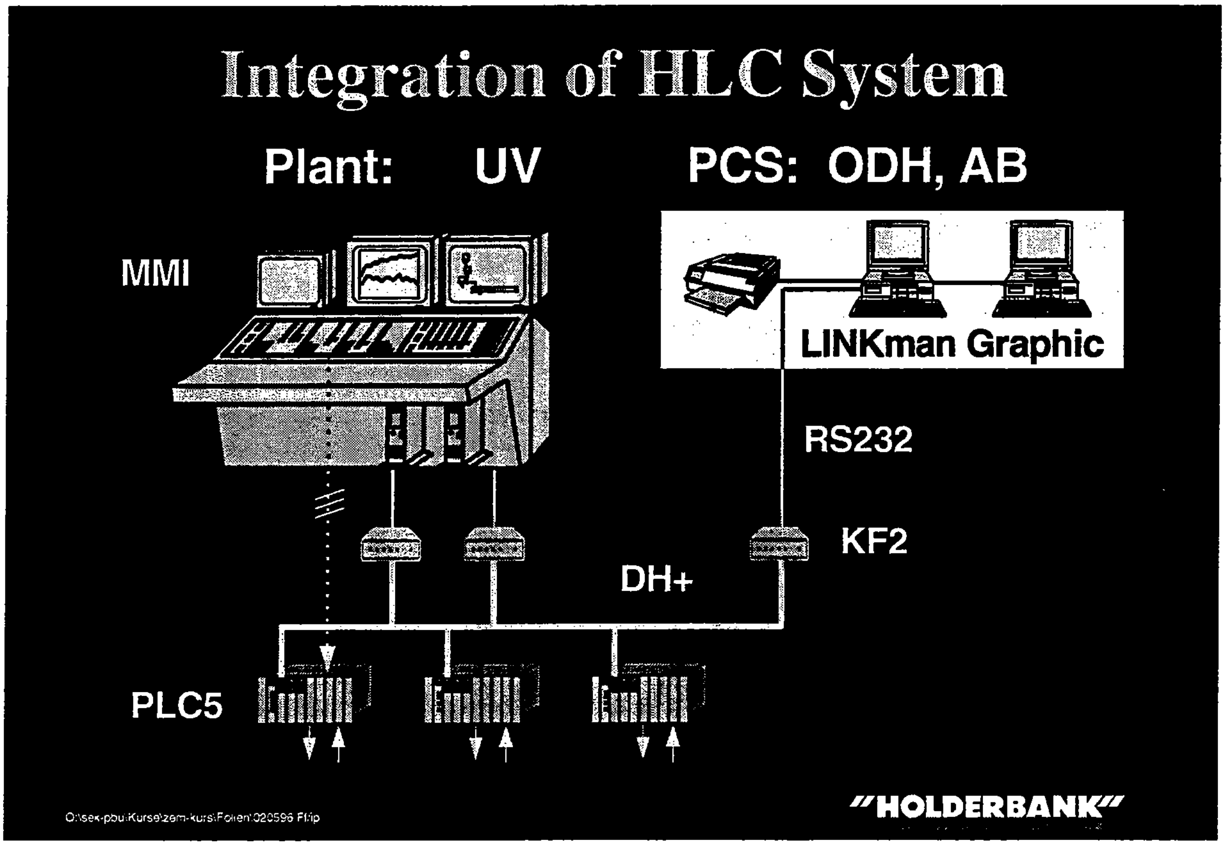
Figure 5:



Integration of HLC System

Plant: UV PCS: ODH, AB

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"HOLDERBANK"

3.1 Data Exchange

The PCS does not only act as data acquisition system for the LINKman II, it serves also as operator interface (MMI, setpoint change, manual mode control), it hosts the basic loop controller, is responsible for automatic/manual switching including fail safe procedure if the LINKman II or communication breaks and does the alarm handling for the whole process (also HLC alarms). Because of this, the communication data set consists not only of analog inputs and outputs, but also of digital signals:

- Digital control bits from the PCS (digital inputs)
- Digital alarm and status bit from the HLC (digital outputs)

DIGITAL INPUTS

The PCS system has to provide different status bits from the process to indicate specific conditions which the LINKman II needs to work for proper operation.

Example:

- LINKman II on/off
- failure of instrumentation
- group ready/running
- direct/indirect operation of raw mill
- select status (type of cement etc.)

DIGITAL OUTPUTS

In a similar way, the LINKman II has to send status bits to the PCS to inform the operator about its status.

Example:

- LINKman II available
- on/off line
- normal condition
- upset condition
- alarms
- etc.

3.2 Security

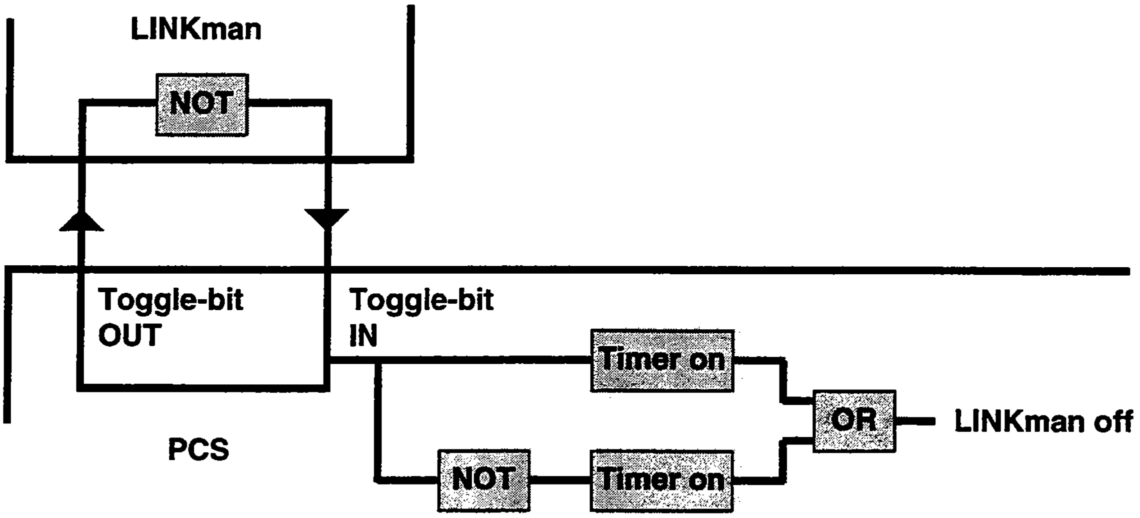
The communication and proper execution of the program have to be guarantied. Therefore, a watch-dog function on the PCS has to be realised:

Example:

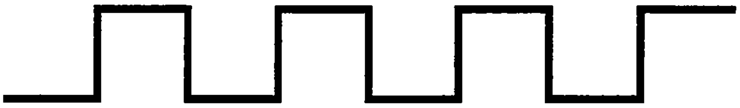
Communication/HLC watch-dog

To check the communication as well as the LINKman II operating status (HLC on or off), a watch-dog toggle-bit has to be programmed.

Figure 6:



If the LINKman and the communication are on, the toggle-bit oscillates



The two on-delay timers control the on- and the off-time of the toggle-bit. If the time exceeds the pre-set delay time of the timers (typical 30 s), the toggle-bit has not been inverted and this means, that the LINKman II or the communication is off.

The PCS is responsible to switch the HLC on- or off-line (on operator's request) and to monitor the HLC's on/off-state feedback and to switch the setpoint signals accordingly (setpoint from operator MMI or from HLC). If the HLC goes off-line and the watch-dog detects a problem, the setpoint will be set to the operator control and an alarm has to be evoked.

Note: The setpoint switching has to be made bumpless. (see PID subject)

4. EXAMPLES OF MOST IMPORTANT INPUTS IN RESPECT OF THE LOCATION AND CALIBRATION OF THE TRANSMITTER

4.1 General

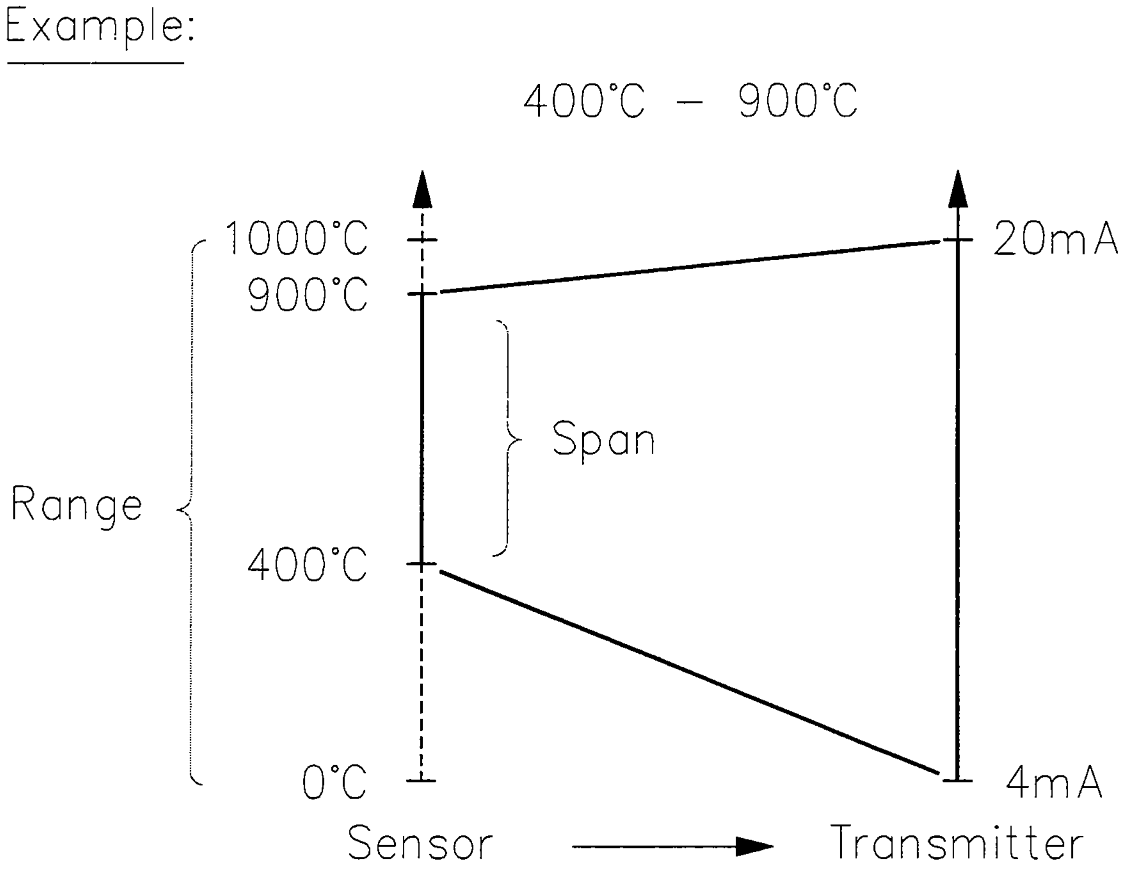
4.1.1 Definition:

Range = Max. - Min. of the sensor

Example: 0°C - 1000°C

Span = Used range for the electrical signal
f or monitoring the process

Figure 7:



4.1.2 Location of the Sensor

The location of the sensor is the most important thing in the instrumentation. There are a few locations which are really false and a lot which are good. For maintenance of the sensors it is quite frequently necessary (especially in the kiln area), that the location of the sensor should be above all easy accessible.

4.1.3 Calibration of the Transmitter

The calibration includes first of all the checking of the transmitter. There are different methods how to check:

1) Reference measurement: The sensor will be tested on a well-defined media (boiling oil, known weight, etc.)
2) Comparison measurement: Measure the process value by an other measuring device (hand-held thermometer/multimeter, pressure U-tube, etc.)
3) Find out the actual physical measurement by measuring the electrical signal coming out of the sensor (only if the characteristics are well-known,should not be used on thermocouple due to the cold reference junction).
4) Simulating the process with an alternative source by entering a calibrated signal on the primary side.

While applying method 1 or 2 as described above, the process value on the highest level (screen of the supervisor or high level control system) - if already installed - has to be monitored. If o.k., the procedure of course is quickly and successfully finished. If not, the output of the transmitter has to be measured by an Amp-Meter (4...20mA) and the transmitter has to be calibrated according its manual. In very seldom cases, the problem is in the scaling of the PLC or the supervisory system.

Note: Two hints on calibration

* Do a Plausibility Check. This means that the signal should be checked of its plausibility. Is it on its expected value? If not, there is something wrong. Do not accept everything you measure. Repeat the measurement if it is not plausible or try to make the calibration by an other way.
* Accuracy. If the sensor is not accurate enough or the transmitter has a too large range, try to calibrate it within the operating range.

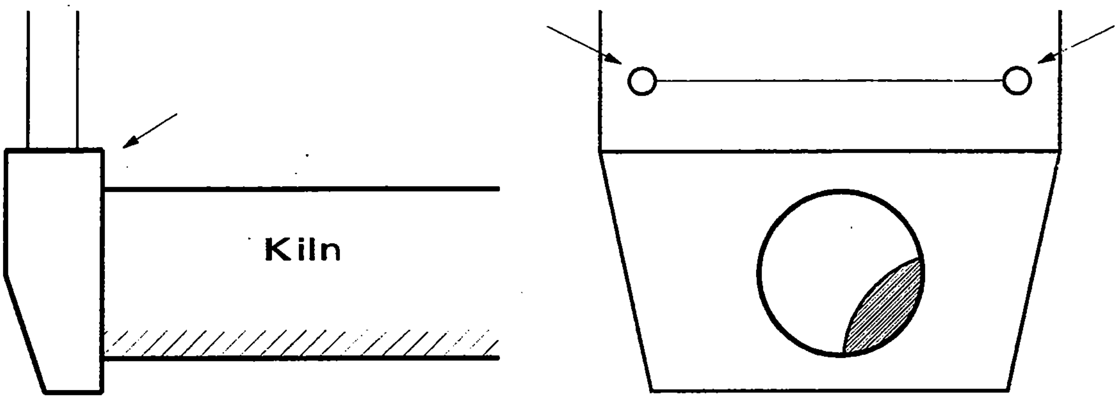
4.2 Examples

4.2.1 Temperature

EXAMPLE 1: KILN INLET TEMPERATURE

LOCATION:

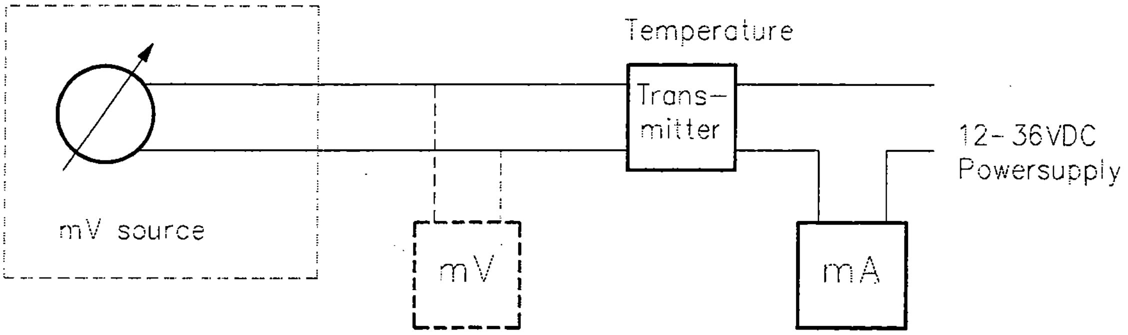
Figure 8:



- Easy accessible for maintenance
- Cleaned by pulling out (daily)
- Tip of sensor should be in the air-stream but not affected too much by incrustation
- Sensor should not be damaged by falling material
- The final position has to be evaluated

CALIBRATION:

Figure 9:



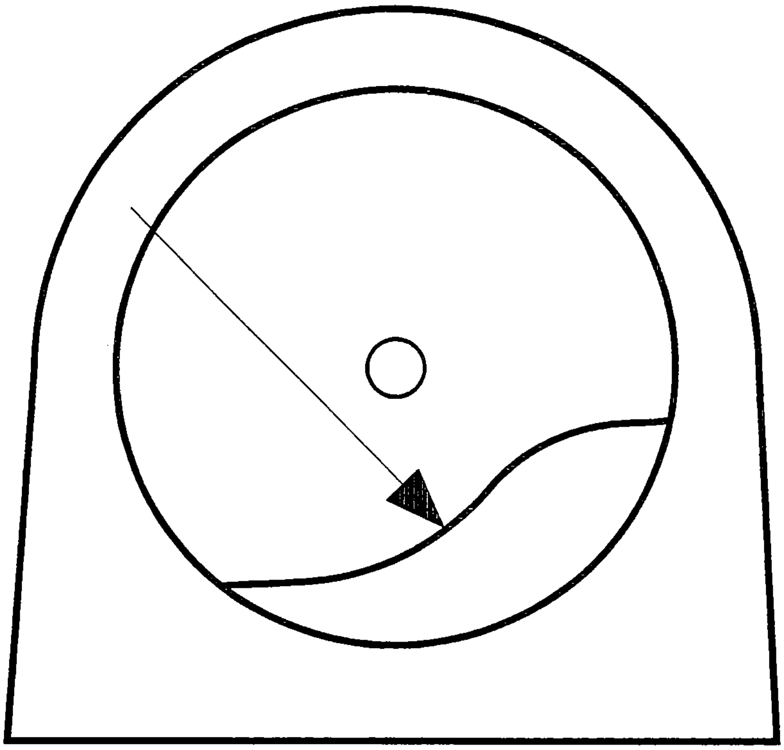
- Inject a voltage in mV without the sensor into the transmitter, while measuring in the 4...20mA line. Take readings at the display for 0 and 100%.

SPAN:						
	minimum:	0%	=	1000°C	=	4.0mA
	maximum:	100%	=	1250°C	=	20.0mA
	unit:	1%	=	2,5°C	=	0.16mA
	typical value:	80%	=	1200°C	=	16.8mA (16:100x80+4)

EXAMPLE 2: PYROMETER (at kiln hood for clinker temperature)

LOCATION:

Figure 10:



- Aim spot 30 cm (1 foot)
- Do not point into flame (radiation)
- Aim the pyrometer below the flame into the clinker just before the clinker flows out of the kiln
- Dust on the lens of the pyrometer or between lens and clinker affects the measurement, therefore, choose a short measuring distance

CALIBRATION:

- Calibration according to the manufacturer. (Does not have to be calibrated under normal circumstances)

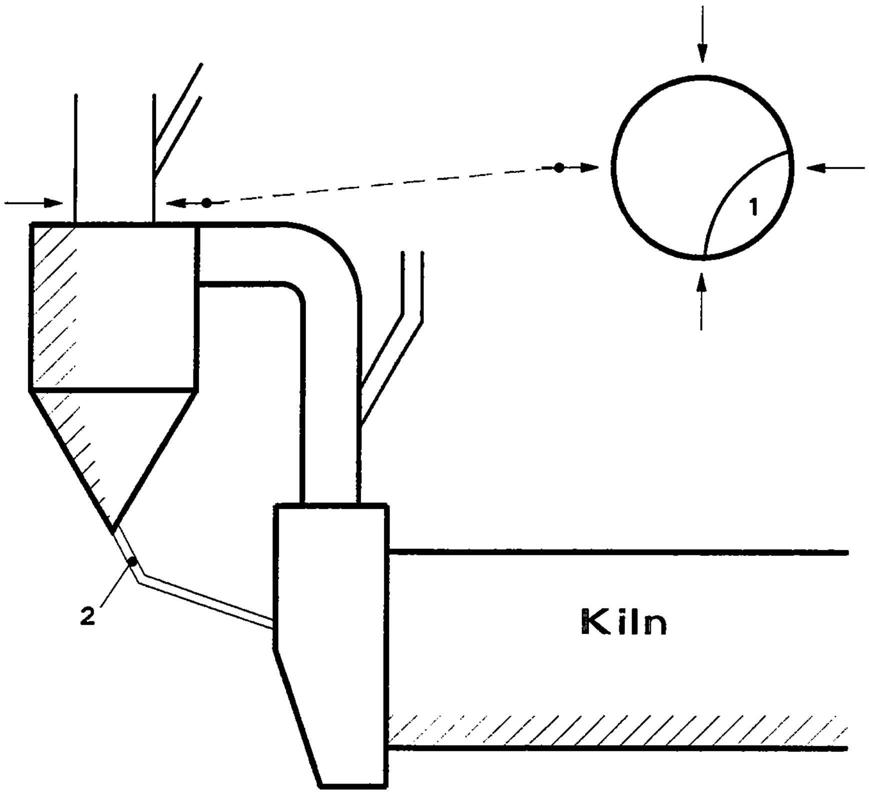
SPAN:	minimum:	0%	=	1100°C	=	4.0mA
	maximum:	100%	=	1600°C	=	20.0mA
	unit:	1%	=	5°C	=	0.16mA
	typical value:	depending on the kiln				

<u>Note</u>: The absolute temperature is not so important, changes have to be monitored.

EXAMPLE 3: PRECALCINER LOWEST CYCLONES

LOCATION:

Figure 11:



1 Dead zone

2 Good position for material temperature

- Find the 2 right locations out of 4
- Parallel probes recommended

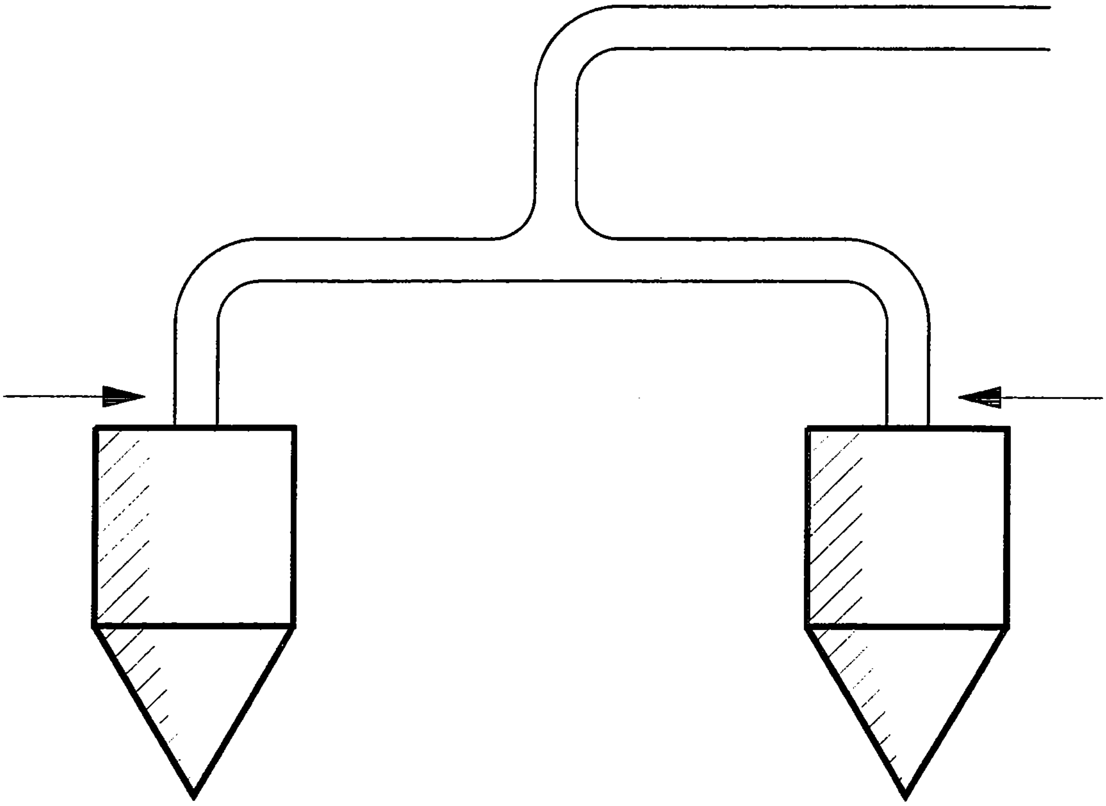
CALIBRATION:

SPAN:	minimum:	0%	=	600°C	=	4.0mA
	maximum:	100%	=	1000°C	=	20.0mA
	unit:	1%	=	4°C	=	0.16mA
	typical value:	72%	=	890°C	=	15.5mA (16:100x72+4)

EXAMPLE 4: PREHEATER EXIT TEMPERATURE

LOCATION:

Figure 12:



- Good for minimizing of exhaust gas temperature
- Equilibrium of tower streams
- If the temperature of the second stage is more indicative, it is advantageous to use this value

CALIBRATION:

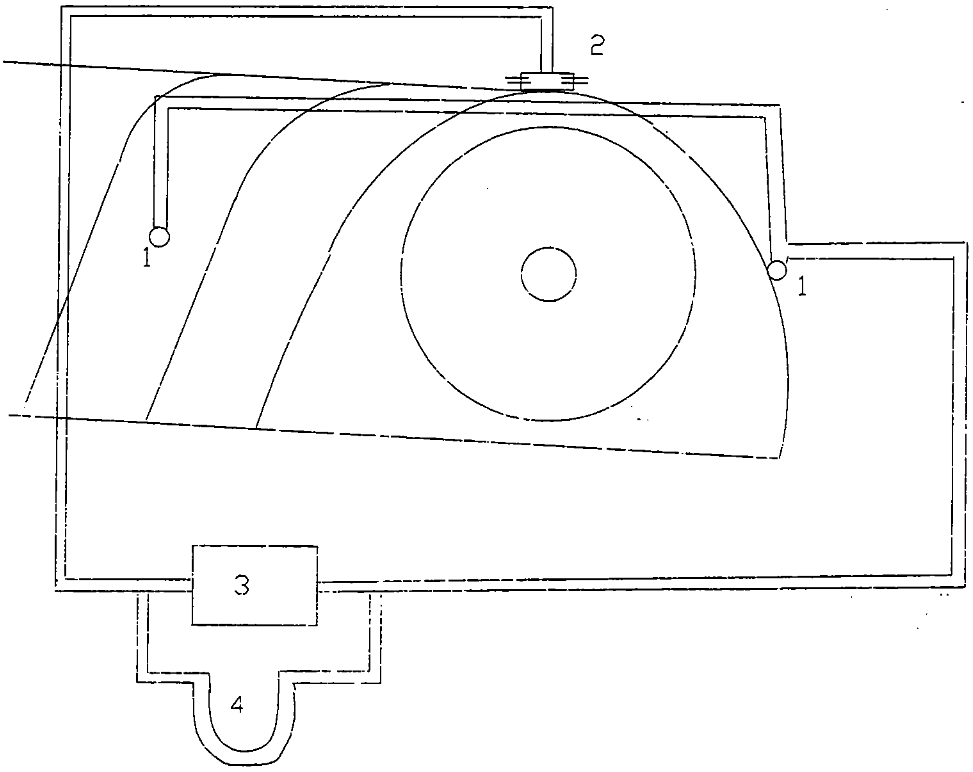
SPAN: minimum: 0% = 0°C = 4.0mA
maximum: 100% = 500°C = 20.0mA
unit: 1% = 5°C = 0.16mA
typical value: 70% = 350°C = 5.2mA (16:100x70+4)

4.2.2 Pressure

EXAMPLE 1: KILN HOOD

LOCATION:

Figure 13:



1	Measuring points (hood pressure)
2	ambient pressure (heated up air)
3	transmitter
4	U- Tube for calibration purpose

CALIBRATION:

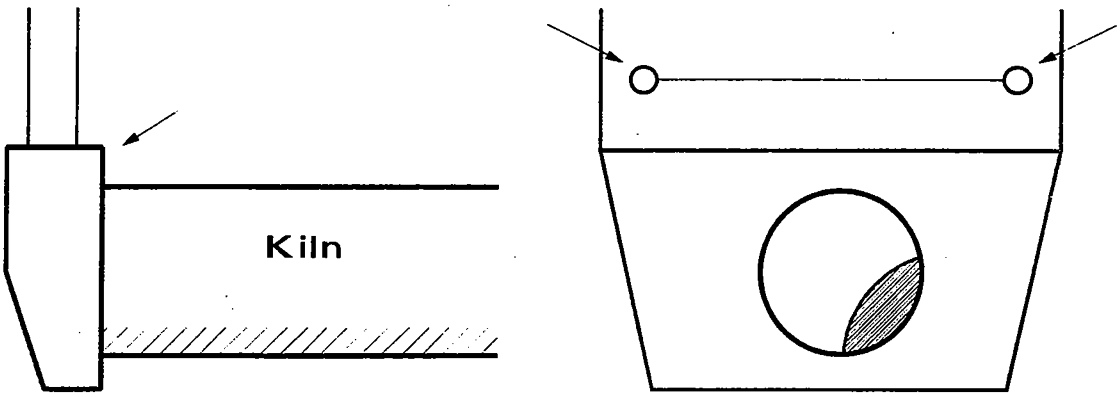
- Measure the pressure by an U-Tube (differential measurement)

grate cooler:	SPAN:	minimum:	0%	=	0.1mbar	=	4.0mA
		maximum:	100%	=	-0.3mbar	=	20.0mA
		unit:	1%	=	0.004mbar	=	0.16mA
	typical value: 37.5% = -0,05mbar = 10.0mA (16:100x37.5+4)						
planetary cooler:	SPAN:	minimum:	0%	=	-2mbar	=	4.0mA
		maximum:	100%	=	-3mbar	=	20.0mA

EXAMPLE 2: KILN INLET PRESSURE

LOCATION:

Figure 14:



- Daily cleaning required
- Indicates ring formation, limits max. production

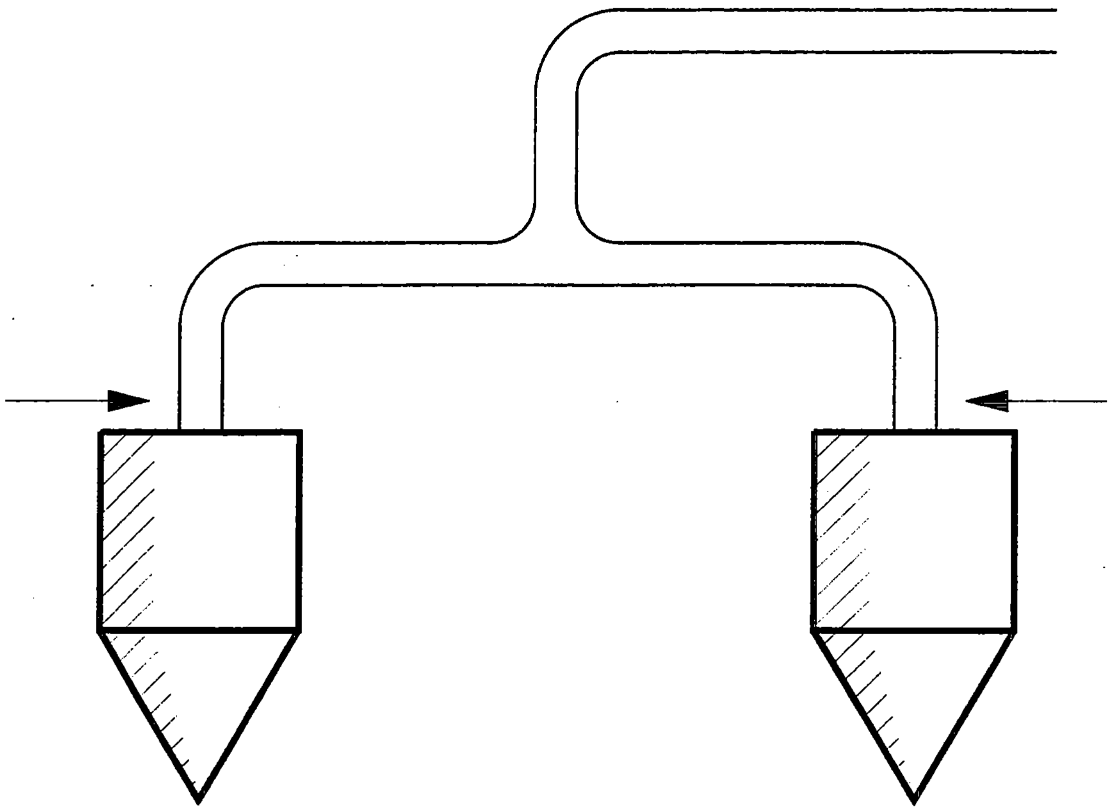
CALIBRATION:

grate cooler:	SPAN:	minimum:	0%	=	0mbar	=	4.0mA
		maximum:	100%	=	10.0mbar	=	20.0mA
		unit:	1%	=	0.1mbar	=	0.16mA
		typical value:		=	2-4mbar		
planetary cooler:	SPAN:	minimum:	0%	=	0mbar	=	4.0mA
		maximum:	100%	=	10mbar	=	20.0mA
		typical value:		=	3-7mbar		

EXAMPLE 3: PREHEATER EXIST PRESSURE

LOCATION:

Figure 15:



- Please note, that this pressure may be different from the ID-fan inlet pressure because of the resistance in the tubes.

Typical value: 5mbar

i.e. 5mbar pressure difference from preheater top to
ID-fan (at bottom, difference in height : 100 m)

CALIBRATION:

grate cooler:	SPAN:	minimum:	0%	=	0mbar	=	4.0mA
		maximum:	100%	=	10.0mbar	=	20.0mA
		unit:	1%	=	1mbar	=	0.16mA
		typical value:		=	40-60mbar		

4.2.3 Speed

EXAMPLE: DC-DRIVE KILN

LOCATION:

- DC-Drive Panel. Usually the transmitter is in the panel as well.

CALIBRATION:

- By a hand-tachometer (analogous or digital) on the kiln motor or motor coupling.

SPAN:	minimum:	0%	=	0rpm	=	4.0mA
	maximum:	100%	=	1500rpm	=	20.0mA
	unit:	1%	=	15rpm	=	0.16mA
	typical value:	85%	=	1275rpm	=	17.6mA (16:100x85+4)

4.2.4 Current

EXAMPLE: KILN DRIVE CURRENT

LOCATION:

- DC-Drive Panel. Usually the transmitter is in the panel as well.

CALIBRATION:

- By the Amp-meter on the DC-drive panel while measuring in the 4...20mA line.

SPAN:	minimum:	0%	=	0A	=	4.0mA
	maximum:	100%	=	1000A	=	20.0mA
	unit:	1%	=	10A	=	0.16mA
	typical value:	30%	=	300A	=	4.8mA (16:100x30+4)

IMPORTANT:

- The kiln amps are used to indicate the torque (and with the torque the:
  - coating falling
  - hot or cold clinker)
    If the field current is not kept constant by a thyristor controlled unit, the kiln drive amps have to be multiplied by the field current.
- The value has to be filtered in case of a planetary cooler, but in a way that ring breaks still can be registered
- Span must be 100% nominal motor current

4.2.5 Power/Energy

EXAMPLE: POWER OF MILL DRIVE

LOCATION:

- Medium-voltage Switchgear.

CALIBRATION:

- Calibration is usually not necessary. For checking the value, it can be calculated: voltage (phase to phase) x current x 1.732 (square root of 3) x power factor (cosø, see motor data, typical 0.97).

RANGE:							
	minimum:	0%	=	0kW	=	4.0mA	
	maximum:	100%	=	2000kW	=	20.0mA	
	unit:	1%	=	20kW	=	0.16mA	
	typical value:	98%	=	1960kW	=	19.68mA	(16:100x98+4)